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THE USE OF DIGITAL MULTISPECTRAL VIDEO FOR LITTORAL ZONE APPLICATIONS

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ABSTRACT

Digital multispectral videography was obtained over Parramore Island, VA in an effort to extract information concerning vegetation communities, micro elevation changes, soil texture, and soil moisture conditions. These information categories would then be used to assist in tactical near-shore decisions, such as cross country mobility, avenues of approach, bivouac sites, and landing areas, and to also provide greater insight concerning environmental management activities within installation natural resource communities. Flightlines extending from the open ocean to the bayside lagoons were collected at both 0.25 meter and 0.5 meter ground spatial resolution. Through image analysis and ground truth verification, the multispectral videography was successful in separating the basic ecological communities of seaside beach, undulating dune-ridge/valley complex, maritime forest, salt marsh, tidal flat, and bays.

INTRODUCTION

The primary mission of the U.S. Army Topographic Engineering Center (TEC) is to provide new topographic capabilities to the warfighter to ensure superior knowledge of the battlefield. This mission is accomplished through research, development, and application of remote sensing, geographic information, global positioning, topographic and information technologies. In particular, remote sensing technology offers a unique capability for rapidly describing, characterizing, and analyzing the surface of the earth. Emerging commercial satellite sensors will be routinely acquiring information about the earth's surface at a ground detection resolution (GDR) of 4 meters in the multispectral domain, and 1 meter panchromatic (i.e., Earthwatch Quickbird). The value of high resolution multispectral imagery towards the ultimate exploitation of terrain feature and attribute data is of obvious interest to the Army and to the other DoD services alike. Airborne sensors, such as digital multispectral video, are capable of capturing imagery at spatial and spectral resolutions that closely approximate U.S. commercial ventures planned for production acquisition in 1998.

The littoral zone represents a physical environment of joint-service tactical interest. Expedient and efficient movement of troops and equipment within a littoral zone depends upon accurate characterization of the earth's surface and bathymetric conditions. Military planning decisions are made regarding bivouac siting, cross-country mobility, near-shore ship movements in support of logistics or tactical assaults, and line-of-sight dependent missions based in part on the available terrain information. Improvements in terrain characterization and an ability to provide more detailed structural data assists a

military commander in operational decision-making. A critical issue facing the hydrographic and topographic mapping communities is the development of techniques that allow smooth transitions from a hydrographic product, to a littoral product, to a topographic product.

From an ecological perspective, the littoral zone represents an ecoregion sensitive to disturbance. Examples of disturbance caused impacts include such activities as vegetation destruction, beach erosion, soil compaction, and invasive plant species introduction. Multispectral video remote sensing is a tool with high potential for examining environmental issues such as these. In May 1997, the Assistant Secretary of the Army (Installations, Logistics, and Environment) and the Assistant Secretary of the Army (Research, Development, and Acquisition) established a goal to achieve, through technology development and exploitation, environmentally compatible installations and systems without compromising readiness of training (ACTT, 1997). Remote sensing technology is a candidate to satisfy this objective through the establishment of baseline terrain characterization maps, identification of disturbance areas, and identification of terrain features necessary for newly created terrain models.

This research will prototype techniques for development of combat chart quality products of the littoral zone, augmenting the mapping process currently in-place with spectrally and ecologically derived predictive mapping models. To accomplish this overarching goal, the following research objectives are defined: prototype the advantages and understand the limitations of high resolution spectral imagery for capturing battlespace-relevant terrain data; identify and classify terrain data using either direct spectral relationships or predictive (inferential) methods derived from statistically validated terrain associations; identify anthropogenic or naturally occurring disturbances within the imagery; and briefly examine the value-added reliance of an airborne platform digital multispectral system, as opposed to a spaceborne platform for data acquisition.

Accurate generation of tactical terrain data for modeling and decision making is critical. Of particular interest to this research project is the ability to extract vegetation species from imagery and predict soil conditions (texture, moisture, compaction), micro relief and salinity as an indirect by-product. These variables are difficult to acquire remotely, and costly to acquire in the field. Figure 1 represents a prototype model for determining these terrestrial data from remotely acquired imagery.

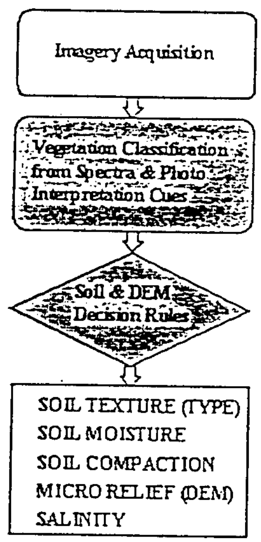

Figure 1. Terrain Data Generation Prototype Model

SITE DESCRIPTION

Parramore Island is located on Virginia's eastern shore and is part of the Virginia Coast Reserve (VCR), Long-Term Ecological Research (LTER) system. The central hypothesis of the VCR-LTER is that ecosystem, landscape, and succession

changes within wetlands are regulated by the relative vertical (topographic) positions of the land, sea, and fresh water tables. Changes in position of these free surfaces may result either from disturbances occurring within short-time intervals, such as storm events, or during longer periods of time, resulting from sea level rise. Parramore Island is part of a chain of barrier islands that comprise the eastern shore's beach, barrier island and lagoonal coastal complex of the Atlantic Ocean. The barrier island's geomorphic development is predominantly controlled by the oceanic effects of wind, water, and tidal influences as well as storm events. Moving westward from the sea, the island can be segmented into six major classes: seaside beach, undulating dune-ridge/valley complex, maritime forest, salt marsh, tidal flat, and bays.

The beach region is dominated by sand and generally devoid of vegetation because of the tidal influence; however, a transition zone occurs in the area seaside of the dune region that includes several native and invasive grass species. The transition into the dune-ridge region is abrupt on Parramore. Increased severity of storm and tidal events, associated with global sea level rise, are serving to erode sections of the forest cover, extending the beach into areas formally occupied by dunes.

The dune-ridge/valley complex is a successive, undulating system formed by wind and tidal events. The main ridge, Italian Hill, is a large dune rising approximately 10 meters above sea level. The soils in the dune region consist of stratified complexes with poorly developed organic A horizons. The remaining soil horizons are comprised of well-drained sands of similar sedimentary origin. Theses horizons are stratified based on the depositional forces from which they were formed (wind or flooding). The dominant vegetation is Loblolly pine with a scattered shrub layer (*Myrica sp.* and *Iva sp.*) that makes up the understory community. Collectively, this area is identified as maritime forest.

Lower elevations occurring sound-side of the dune system and maritime forest foster the development of salt marshes. The marsh systems nearest the dunes are dominated by salt marsh cordgrass (*S. patens*) that typically occupies areas of irregular flooding. Soil development in this region is comprised of a well-developed peat horizon up to 0.5 meters overlaying sand. This region gives way to another smaller ridge system before entering the tidal flat zone.

The tidal flat is regularly inundated and dominated by tall and short form smooth cordgrass - *S. alterniflora*. *S. alterniflora* occupies areas of varied soil types and the form it takes is governed strongly by ground water influx and salinity. Where salinity levels are high, the short form of cordgrass dominates. Large freshwater inflows stimulate the growth of the taller form of this species. In many cases, subtle topographic gradients govern these changes. When coupled with groundwater inflow and soil mineralization, these areas will develop peat layers overlaying sandy soils. The tidal flat system extends landward to the edge of the lagoonal bay. A comprehensive description of the Virginia barrier island ecosystem can be found in McCaffrey and Duesser (1990).

DATA DESCRIPTION

The digital imagery collected for this project was obtained by TEC's Specterra Digital Multispectral Video system (DMSV). The DMSV system is comprised of four charged coupled device (CCD) cameras with 12-mm focal length lenses, a ruggedized 486 PC, 32 Mb of RAM, a 500 Mb hard disk, and a 4 Mb AT framegrabber board. Each of the four cameras were fitted with a 25-nm bandpass interference filter. These filters were centered at 450-nm, 550-nm, 650-nm, and 750-nm, respectively. The four bands are captured simultaneously and stored on internal RAM. Each 8-bit, 740 by 578 pixel four-band frame is a little over 1.7 Mb in size, which allows for the collection of 17 frames before the data must be transferred to the PC hard drive.

The Virginia Institute of Marine Science (VIMS) DeHaviland "Beaver" served as the aerial platform for this project. The imagery was collected on 25 February 1998 (1300 EST) at an altitude of approximately 2,500 feet and 5,500 feet above mean sea level, which resulted in a spatial resolution of approximately 0.25 m/pixel and 0.5 m/pixel, respectively. A first-order, six-parameter affine transformation was used to merge each frame in a flightline. Ground Control Points (GCPs) were selected by an analyst and the root mean square error (RMSE) of the transformations was kept below 1.0 pixels. Within flight-line radiometric discontinuities caused by vignetting, optical and geometrical effects were addressed using a method similar to Pickup (1995, 1996) and Neale, et al. (1996). An empirical calibration matrix to counteract the radiometric discontinuities was created using the DMSV data itself. This technique masks out common cover type pixels from each

image in an effort to estimate within frame radiometric variation. The average mask from each cover type in theory should be radiometrically flat; any deviation from this "flat" image would caused by one, or a combination of the above, effects. An inverse mask was then derived from the masked images and applied to every frame.

PRELIMINARY RESULTS AND DISCUSSION

Figure 2 shows a cross-section of Parramore Island flown at 5,500 feet above the terrain (~ 0.5 meter/pixel). This image is the 650 nm band (red) from the DMSV system. The DMSV imagery was used to combine the six specific coastal regions into four broad classes; seaside beach zone, coastal marsh, maritime forest and bayside marsh.

The seaside beach zone, denoted by the box marked region 1, is characterized by open ocean, swash zone, beach, and near-beach vegetation. The relative dimensions of the beach and swash zone is directly dependent on tide and wave activity. The near-beach vegetation consists predominantly of stunted loblolly pine and understory shrubs. The soil consists of nearly 100 percent sand with varying amounts of overlying storm drift material. The vegetation closest to the beach may be suffering from salt induced stress that could possibly be detected remotely. In this region, foot and vehicle mobility would be relatively easy on the open beach, but considerably more difficult in the loblolly communities.

The coastal marsh region, denoted by box number 2, is characterized by the tall form of salt cord grass growing in saturated conditions. The soil consists of a fairly deep organic layer overlying a sand base. Mobility through this region can be difficult depending upon soil saturation and cord grass density. Overhead cover is poor as their is a lack of tall vegetation. Areas of coastal marsh are found between dune-ridge structures where soil salinity does not reach excessive levels.

The maritime forest region is shown in box number 3. This area corresponds to the well known Italian Hill or Italian Ridge feature. Terrain elevations reach to 10 meters above mean sea level. The dominant vegetation is loblolly pine with scattered American holly and other understory vegetation. Soil conditions consist of a pine needle duff layer overlying sand. Soil conditions are more uniform in this region as the duff layer tends to trap moisture from precipitation. The loblolly pine can grow up to 70 feet in height, creating in some places an almost enclosed canopy that provides reasonable cover for movement and bivouac. Because of reduced lighting, understory vegetation is sparse, which allows for easy foot traffic. Vehicle traffic may be somewhat impeded due because of the large trunks of the mature loblolly trees.

The bayside marsh system is noted by the box marked region 4. The dominant vegetation in this area is the short form of salt cord grass. This area is flooded during high tide and exposed at low tide. No vegetation is found on the steep creek banks because of high water velocities and longer periods of flooding. Soil conditions consist of an organic layer (~ 0.3 meters) over a sand substrate. A considerable amount of shells also can be found in certain localities. Within the bayside marsh area, terrestrial foot and vehicular traffic will be difficult under most conditions. Line of site is good, however overhead cover is poor because of relatively short vegetation (< 1 meter).

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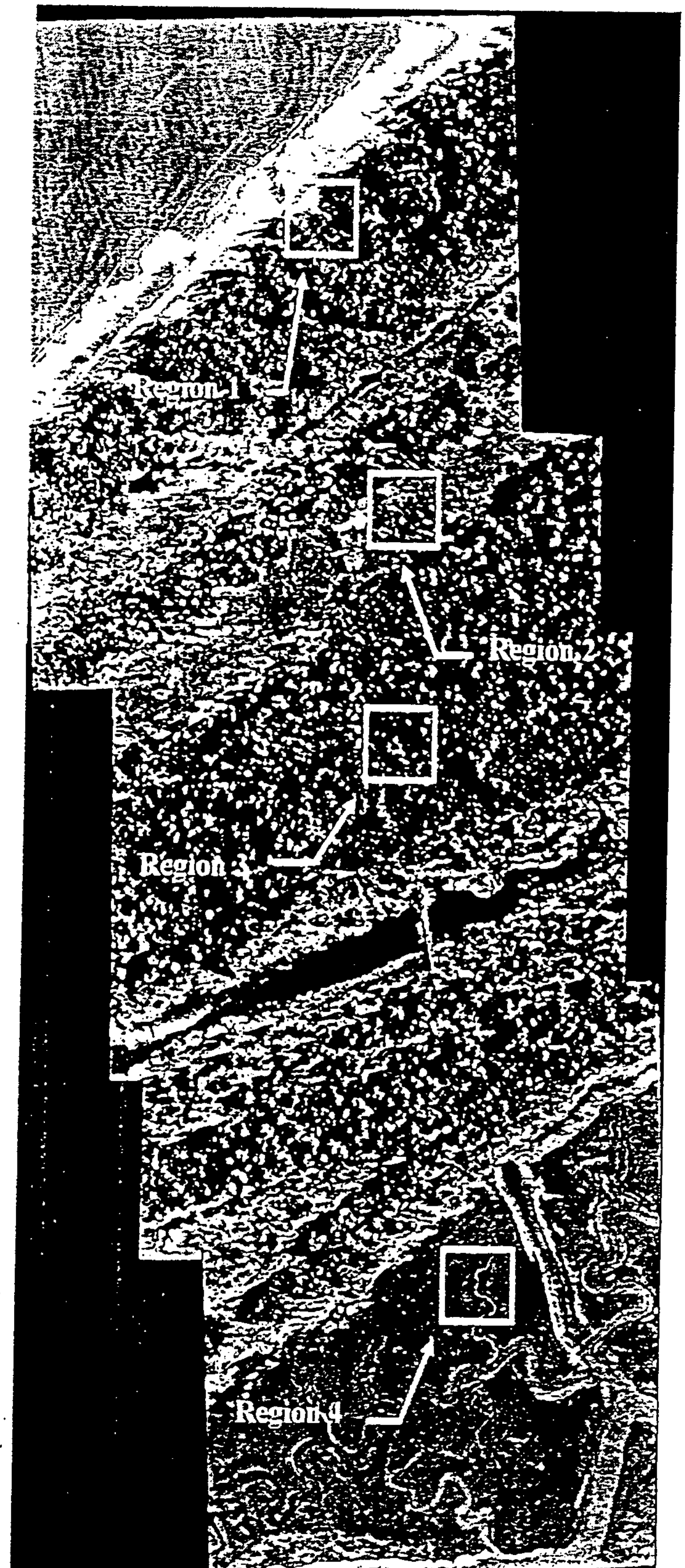

Figure 2